

¹⁵N-RICH ORGANIC GLOBULES IN A CLUSTER IDP AND THE BELLS CM2 CHONDRITE.

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Introduction: Organic matter in primitive meteorites and chondritic porous interplanetary dust particles (CP IDPs) is commonly enriched in D/H and ¹⁵N/¹⁴N relative to terrestrial values [1-3]. These anomalies are ascribed to the partial preservation of presolar cold molecular cloud material [1]. Some meteorites and IDPs contain μm-size inclusions with extreme H and N isotopic anomalies [2-4], possibly due to preserved pristine primordial organic grains.

We recently showed that in the Tagish Lake meteorite, the principle carriers of these anomalies are sub-μm, hollow organic globules [5]. The globules likely formed by photochemical processing of organic ices in a cold molecular cloud or the outermost regions of the protosolar disk [5]. We proposed that similar materials should be common among primitive meteorites, IDPs, and comets.

Similar objects have been observed in organic extracts of carbonaceous chondrites [6-8], however their N and H isotopic compositions are generally unknown. Bulk H and N isotopic compositions may indicate which meteorites best preserve interstellar organic compounds. Thus, we selected the Bells CM2 carbonaceous chondrites for study based on its large bulk δ¹⁵N (+335 ‰) and δD (+990 ‰) [9].

CP IDPs often exhibit D- and ¹⁵N-enrichments that exceed typical values of most meteorite organics [2,4]. CP IDPs have moderate bulk D/H and ¹⁵N/¹⁴N enrichments as well as extreme enrichments at μm-scales (δD > 10,000 ‰; δ¹⁵N > 1,000 ‰) [2]. Carbonaceous matter in these particles is so abundant (>3x CI chondrites) that it is often the principle matrix that binds the particles together. It is not yet known whether the D- and ¹⁵N- rich ‘hotspots’ in IDPs are associated with organic globules.

Here we present the results of a search for organic globules in a cluster interplanetary dust particle (IDP) and in the Bells CM2 carbonaceous chondrites.

Experimental: Matrix fragments (~20 mm) of the Bells CM2 carbonaceous chondrite and an IDP (L2005 AL5 Cluster 15) were embedded in elemental S for ultramicrotomy. The samples were sliced into 70 nm-thick sections and deposited onto C-coated TEM grids. This sample preparation procedure enables microscopic organic materials to be studied *in situ* while preserving their structures.

The sections were investigated for their major mineralogy and the nature and distribution of carbonaceous materials with a JEOL 2500SE 200kV field-emission scanning TEM (STEM) equipped with a Noran thin window energy-dispersive X-ray (EDX) spectrometer, a Gatan Tridiem imaging filter (GIF) for energy-filtered imaging (EFTEM) and EELS, and a 2K x 2K slow scan CCD camera. EFTEM images were collected with acquisition times of 20-60 s. EELS spectra were obtained in image mode with spot sizes of 10-50 nm, a dispersion of 0.3 eV, dwell times of 10-30 s at an energy resolution of 0.9 eV FWHM at the zero-loss peak.

Isotopic measurements were performed after TEM analysis with the JSC NanoSIMS 50L ion microprobe. Nitrogen, O, and C isotopic images were acquired in multidetection with electron multipliers. Images were obtained by rastering a ~1 pA, <100 nm Cs⁺ beam over 10 - 20 μm fields of view. Each imaging run consisted of repeated (20 - 40) scans over the same area. Electrostatic charging was mitigated with the use of an electron flood gun. Carbon, O and N isotopic images were acquired from 10 μm grains of USGS graphite, San Carlos olivine and 1-hydroxybenzotriazole hydrate (respectively) placed near each sample as external isotopic standards. Images were corrected for EM deadtime, QSA, and instrumental mass fractionation with custom written software.

Results and Discussion: *Cluster IDP L2005AL5:* Investigation by TEM showed this to be a porous, fine grained IDP comprised of anhydrous minerals including enstatite, forsterite, Fe-Ni sulfides, GEMS grains, and several presolar silicate grains [10]. Carbonaceous material is abundant, appearing as grain coatings, veins, and discrete inclusions occasionally as spherical objects (globules). Nitrogen isotopic images of 8 sections of the IDP show that it is ¹⁵N-rich, with a bulk δ¹⁵N = +160 ‰. Several sub-μm ¹⁵N-rich ‘hotspots’ (500 ‰ - 800 ‰) were observed and in several cases these were clearly associated with discrete organic globules akin to those found in meteorites (Fig. 1).

Bells: Organic globules in Bells CM2 matrix are more abundant than in Tagish Lake. Organic globules in Bells CM2 often appear to be aggregates riddled with tiny holes (Fig2). Single hollow globules (Fig2b) similar to Tagish Lake globules are also observed, but are less common. High-resolution TEM imaging and

EELS show that the globules consist of structurally amorphous carbon lacking long range order or development of graphite-like domains. Nitrogen K-edge structure rapidly disappears while acquiring EELS spectra, indicating that the N component in the globules is very beam sensitive. The N abundance is estimated to be < 1wt.% based on the EELS data.

Nitrogen isotopic images of Bells gave similar results to the IDP studied here. Each of the 7 sections analyzed was found to be ^{15}N -rich with bulk $\delta^{15}\text{N}$ values ranging from +80 to 170 ‰. ^{15}N -rich 'hotspots' (500‰ – 2,000 ‰) appeared in all of the sections. Most of the ^{15}N hotspots were clearly associated with previously identified organic globules or globule aggregates.

With the exception of their unusual aggregate morphologies, the physical, chemical, and isotopic properties of organic globules in Bells are similar to those observed in the Tagish Lake meteorite. ^{15}N -rich organic globules are also present in IDPs, but they constitute a minor component of the organic matter. These results support the view that microscopic organic grains were widespread constituents of the protoplanetary disk. Their exotic isotopic compositions trace their origins to the outermost portions of the protosolar disk or a presolar cold molecular cloud.

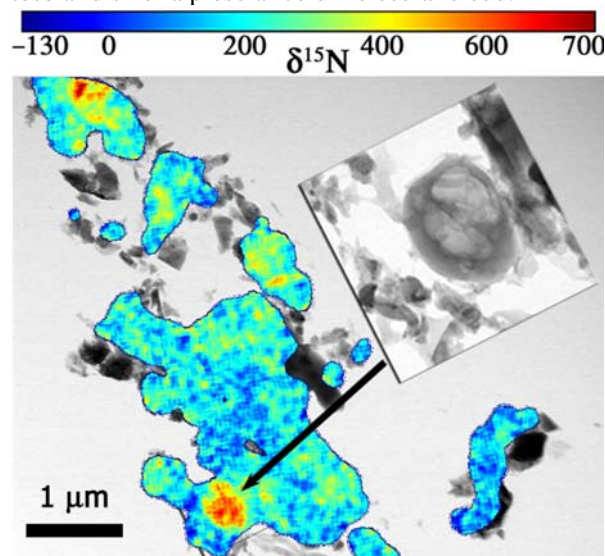


Fig. 1 Brightfield TEM image of IDP L2005A15 overlain with a $\delta^{15}\text{N}$ isotopic image. An organic globule (inset) is identified as the ^{15}N -rich object ($\delta^{15}\text{N}=700$).

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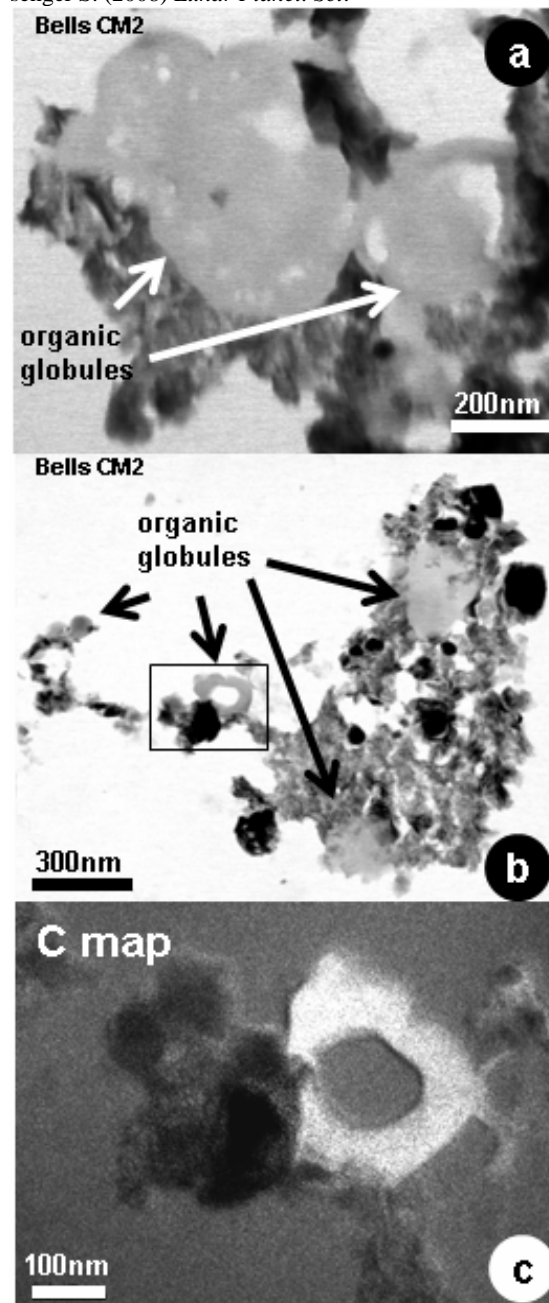


Fig. 2 (a) & (b) Bright field TEM image of organic globule aggregates from Bells CM2 meteorite in a saponite matrix. (c) Carbon K-edge EFTEM image of the boxed area in (b).